Sunspots and Solar Rotation

ASTR1020

Name:

Overview:

This lab will investigate surface features on the Sun and how we can use sunspots to determine the rotation rate of the Sun.

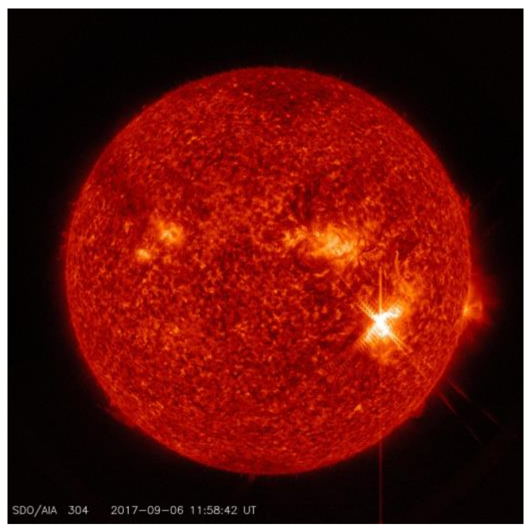
Objectives:

After completing this lab, students will be able to:

- Identify surface features on the Sun
- Calculate the rotation rate of the Sun

Definitions:

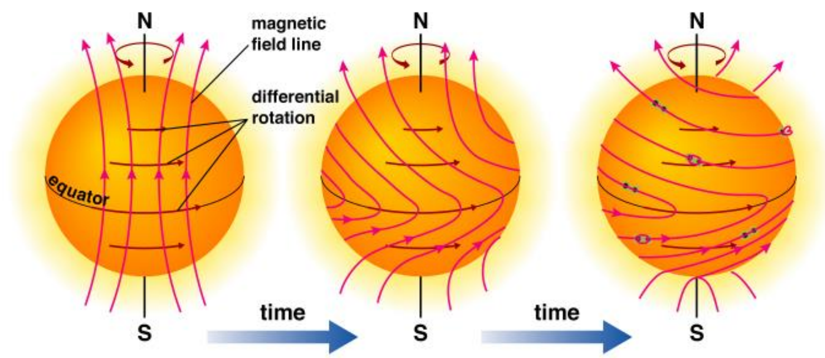
- **Photosphere** – the visible surface of the Sun
- **Chromosphere** – a layer of the Sun's atmosphere
- **Solar Cycle** – approximately every 11 years the Sun's magnetic field completely flips (Sun's north and south poles switch places). The solar cycle affects activity on the surface of the Sun.
- **Sunspots** – areas that appear dark on the surface of the Sun. They appear dark because they are cooler than other parts of the Sun's surface.
- **Solar flare** – an intense burst of radiation coming from the release of magnetic energy associated with sunspots
- **Solar prominence** – a large, bright feature extending outward from the Sun's surface. Known as a **filament** when viewed against the solar disk.



- **Granules** – small (~1000 km) cellular features that cover the entire Sun (minus sunspot areas) caused by convection currents of plasma within the Sun's convective zone.
- **Differential rotation** – rotating at different rates at different latitudes
- **Angular velocity (ω)** – how fast an object is rotating. SI units of inverse seconds (s^{-1})
- **Sidereal Period** – time required for an object to complete one complete rotation related to the "fixed" background of stars. This is an object's true rotation period, as observed with respect to a stationary observer.
- **Synodic Period** – time required for an object to complete one rotation that includes the Earth's motion. This rotation period is not observed with respect to a stationary observer.

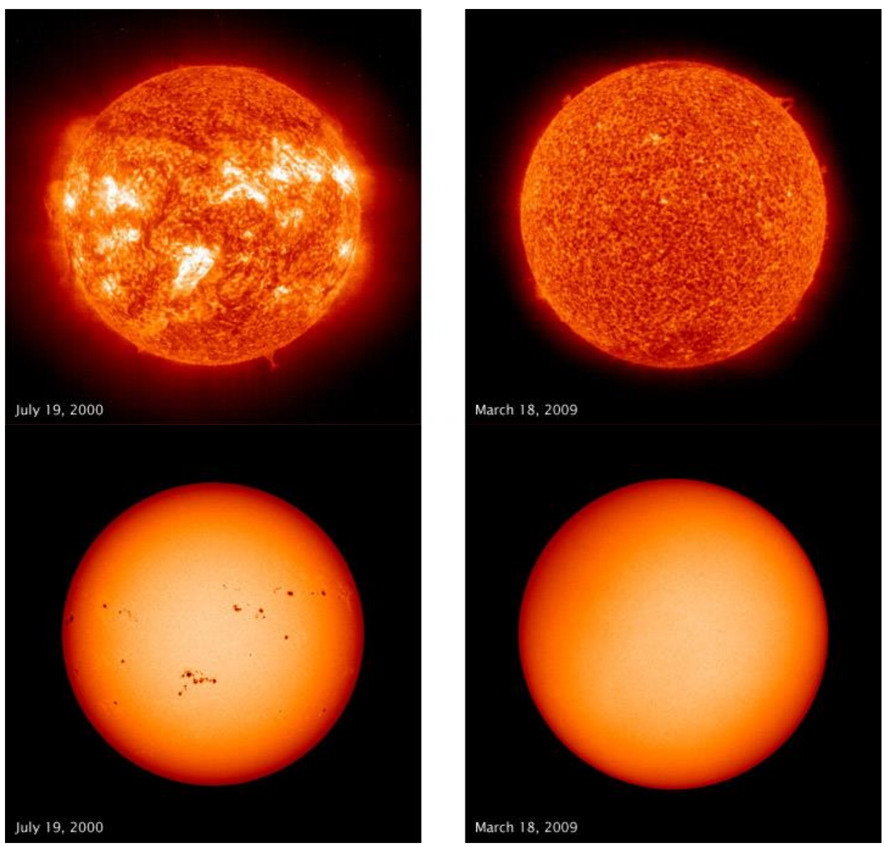
Part 1. Solar Surface Features

The Sun has a magnetic field, just like the Earth does, but unlike the Earth, the Sun is not a solid body. The Sun is made of plasma. Because of this, as the Sun rotates, it does not rotate all together at the same rate. It experiences differential rotation. The plasma at the equator will rotate at a faster rate than at the poles. This differential rotation also affects the magnetic field which gets dragged along with the rotation.



Features that we on the Sun, such as sunspots, flares and prominences, are caused by the Sun's magnetic field twisting up due to differential rotation.

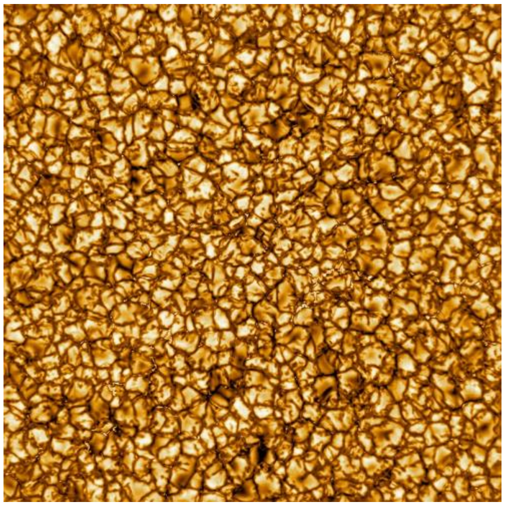
However, these features are not always present due to the Sun's solar cycle. Eventually the magnetic fields will twist so much that they will have flipped opposite to how they began. The flip from one pole to the other takes about 11 years, with a full cycle (meaning the magnetic field lines returning to their initial position) taking about 22 years. During the solar cycle the Sun will experience a solar minimum (nice magnetic field lines pointed up through the poles) and a solar maximum (very twisted magnetic field lines).



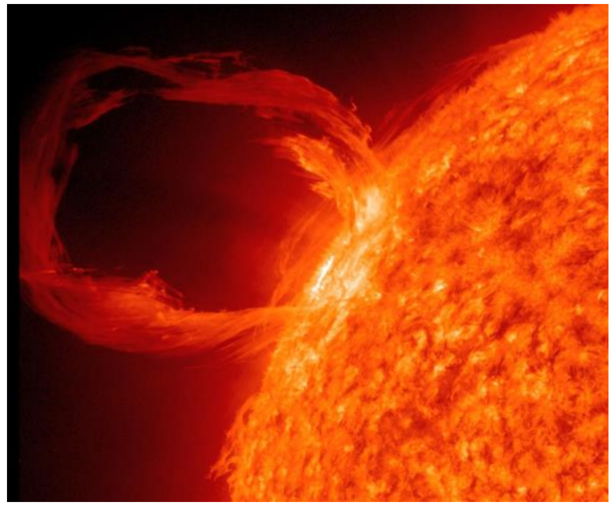
The images on the left show the Sun in two different filters in July 2000 which was near a solar maximum. The images on the right show the Sun in 2009 which was near a solar minimum.

The Sun currently is in a moderately inactive period with few, if any sunspots.

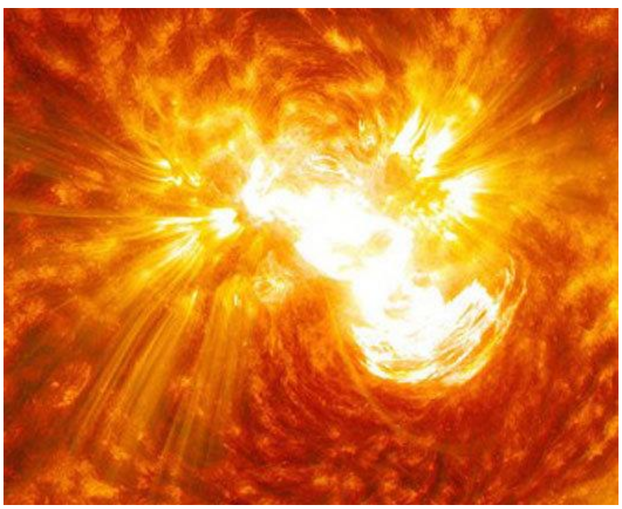
Now that you know what causes these solar features, it is time to identify them! List the solar features present in each image!



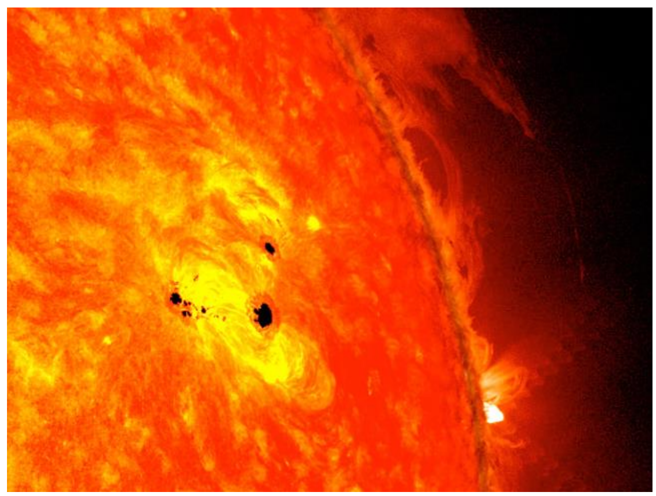
1. Image One



2. Image Two



3. Image Three

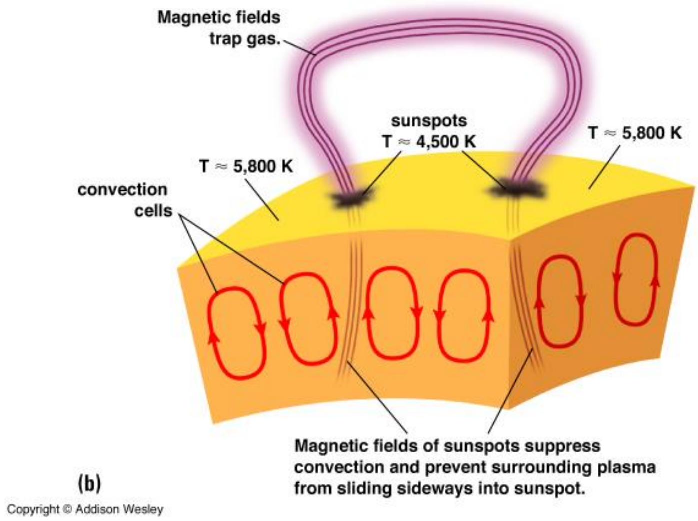


4. Image Four

Image Credits: NASA

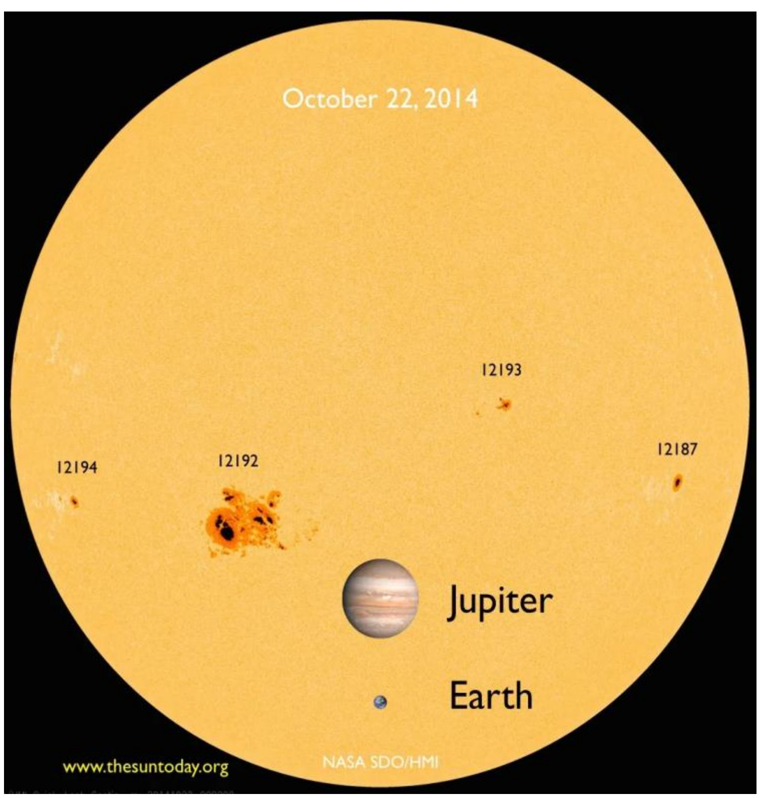
Part 2. Sunspots and how to use them!

Sunspots are features seen in the Sun's photosphere. They may look like holes on the surface of the Sun, but they are actually areas of cooler temperature. About 4000 K compared to the rest of the Sun's surface, about 5800 K. They are caused by the Sun's magnetic field twisting up due to differential rotation.



The magnetic field lines become tightly wound and can poke through the surface layers. The magnetic field blocks the hot surface plasma from filling in the spot it pokes out through, keeping it cooler and making it appear darker.

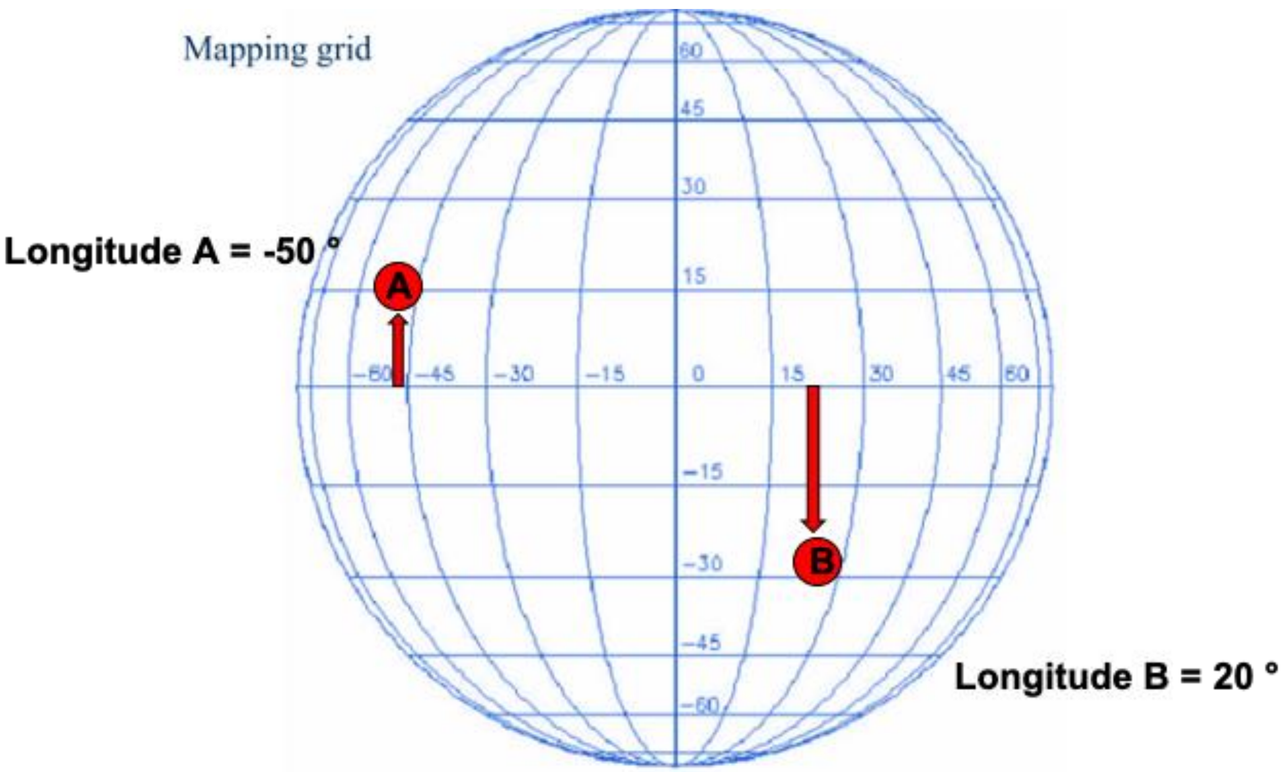
These spots can last up to several weeks, before the magnetic field lines weaken as differential rotation continues. Though these spots look pretty tiny on the surface, they are actually very large, often with a diameter similar to the diameter of the Earth, or bigger. The image below shows Jupiter and Earth for scale next to some sunspots. They often appear in pairs and are located around the Sun's equator.



Sunspots move with the Sun's rotation and by monitoring how long it takes a sunspot to traverse the face of the Sun, we can calculate how fast the Sun must be rotating!

For this activity we will be using images of the Sun from a more active time period. These are real images of the Sun taken over a span of 12 days by SOHO (Solar & Heliospheric Observatory). SOHO is a spacecraft that was launched in 1995 through a collaboration of NASA and ESA to study the Sun and is still in orbit today.

Sunspots remain constant in their latitude as they move across the Sun, so we will be recording their longitudes to calculate the rotation rate of the Sun. In the figure below is an example of how to find the longitude for two sample sunspots.



Record the longitude values of each sunspot in Table 1 using the SOHO images found in the 'SunImages.pdf" file on iCollege (or scroll to the end of this lab). In the images the sunspots are labeled with a white 'A', 'B', or 'C'. You will have images from June 22 to July 3.

Note that not all three groups will be visible in every frame at the beginning or at the end, as some take longer to appear or may disappear sooner than the other groups. If the sunspot is not visible on a given date, put a '-' or 'N/A' in the table.

Table 1. Longitude Values of Sunspots

Date	Spot A	Spot B	Spot C
June 22			
June 23			
June 24			
June 25			
June 26			
June 27			
June 28			
June 29			
June 30			
July 1			
July 2			
July 3			

Part 3. Rotation rate of the Sun

You are now ready to calculate the rotation rate of the Sun! You can do all of the calculations by hand on a paper, but I would recommend copying Table 1 into an Excel file (or the spreadsheet provider of your ex. Numbers on Macs, Calc in LibreOffice). Whatever you choose, **MAKE SURE YOU UPLOAD YOUR MATH WORK WITH YOUR LAB MANUAL to the 'Lab 1 –Sunspots and Solar Rotation' assignment in iCollege!**

5. How many degrees does sunspot Group A move from June 22nd to June 23rd?

6. How many degrees does sunspot Group A move from June 23rd to June 24th?

7. How many degrees does sunspot Group A move from June 24th to June 25th?

Continue this for each of the remaining days (movement from June 25 to 26, June 26 to 27…etc…July 2-3). Once you have found the daily movement, calculate the average rate of movement for Group A. Reminder – to calculate an average you add up all of the values and divide by the number of values you have.

Example:

You have 23, 54, and 72 and want to find the average.

You would add those number and divide by 3:

$$\frac{23 + 54 + 72}{3} = 49.6$$

8. What is the average rate of movement for Group A?

9. How many degrees does Group A move from the first day it appears to the last day it appears?

10. How many degrees does sunspot Group B move from June 23rd to June 24th?

11. How many degrees does Group B move from June 24th to June 25th?

12. How many degrees does Group B move from June 25th to June 26th?

13. Continue this for each of the remaining days. What is the average rate of movement for Group B?

14. How do the average daily movements compare between Group A and Group B?

15. Do you notice any changes in any of the spots as they move from day to day?

16. What is the average daily movement for Group A and Group B? **This value is your angular velocity, ω!!** In our calculation, units for ω will be degrees/day.

ω =

Using your angular velocity value, you can now calculate the synodic period of the Sun using Equation 1:

$$S = \frac{360°}{\omega} \qquad (Equation\ 1)$$

17. What is the synodic period of the Sun? INCLUDE UNITS IN YOUR ANSWER!

S =

If you have been careful in your measurements and calculations, you should get a synodic period close to S=27.3 ± 2 days.

The synodic period is the Sun's rotation as observed from Earth, which means in addition to considering the Sun's rotation the synodic period also considers the Earth's rotation. To calculate the Sun's true rotation period, the sidereal rotation period. To calculate the sidereal period, use your answer from Question 17 and Equation 2 :

$$P = \frac{(365.25 * S)}{(365.25 + S)} \qquad (Equation\ 2)$$

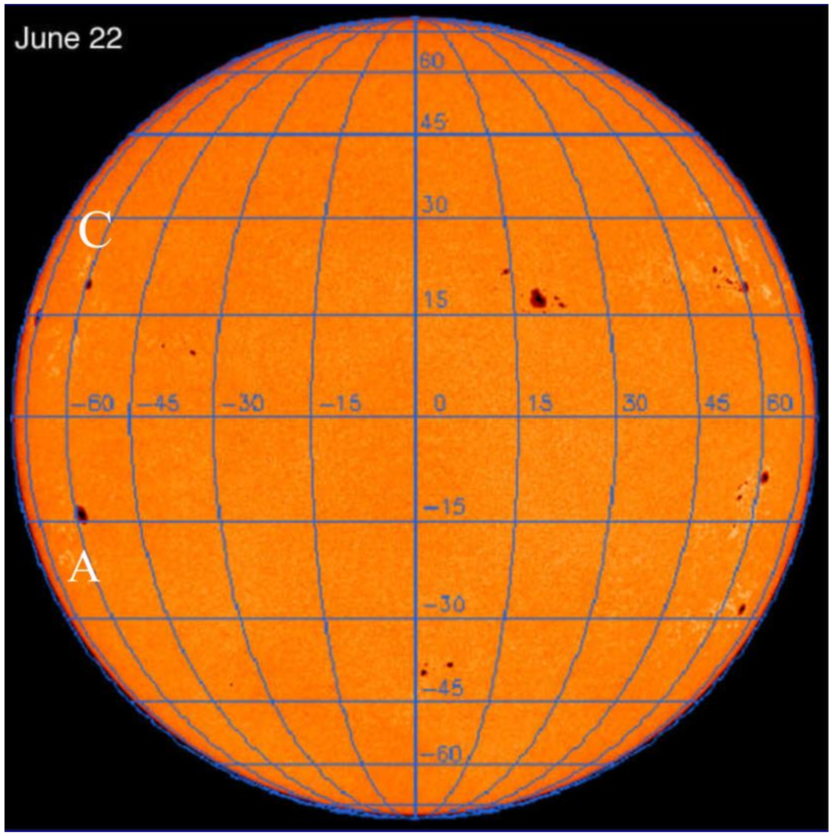
18. What is the sidereal period of the Sun? INCLUDE UNITS IN YOUR ANSWER!

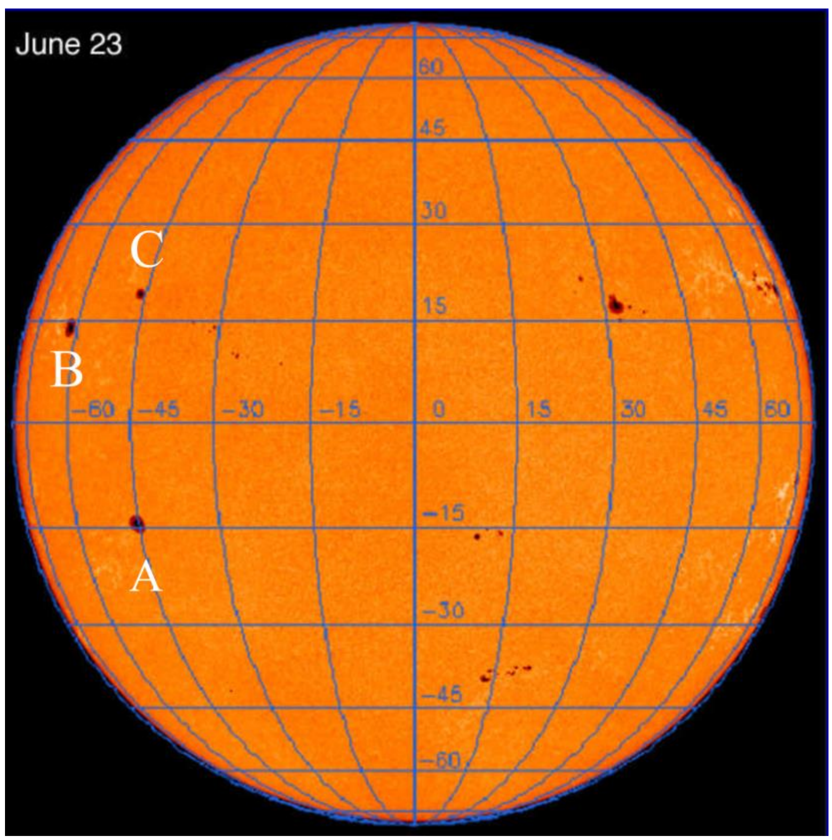
P =

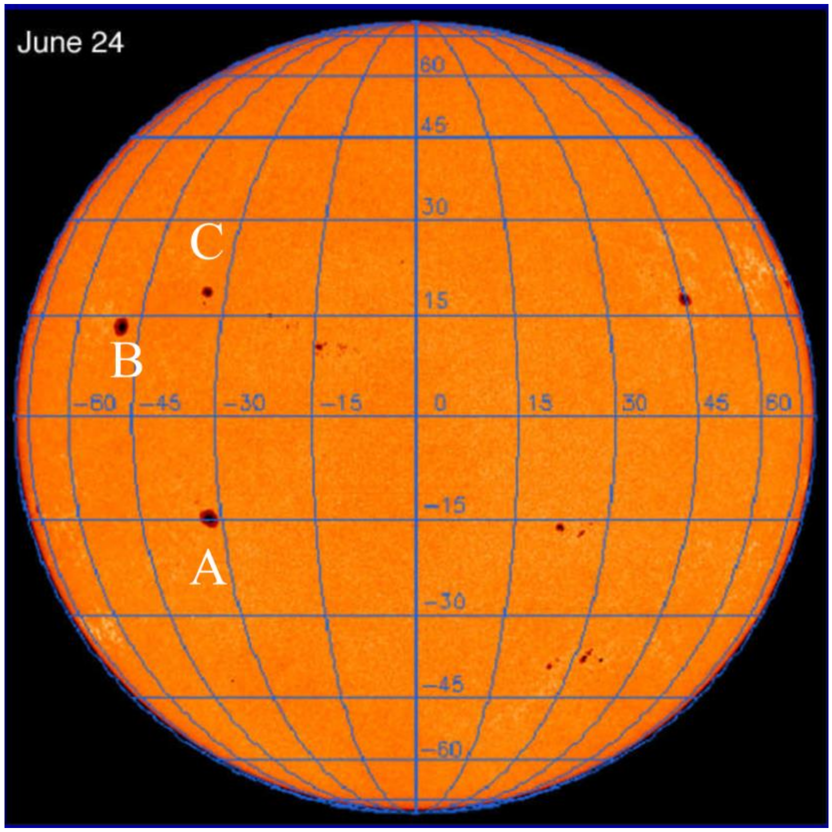
Part 4. Final Thoughts

19. We can only ever see about half the Sun at a time. What do you think the other half looks like? Are there sunspots there? If yes, how many do you think?

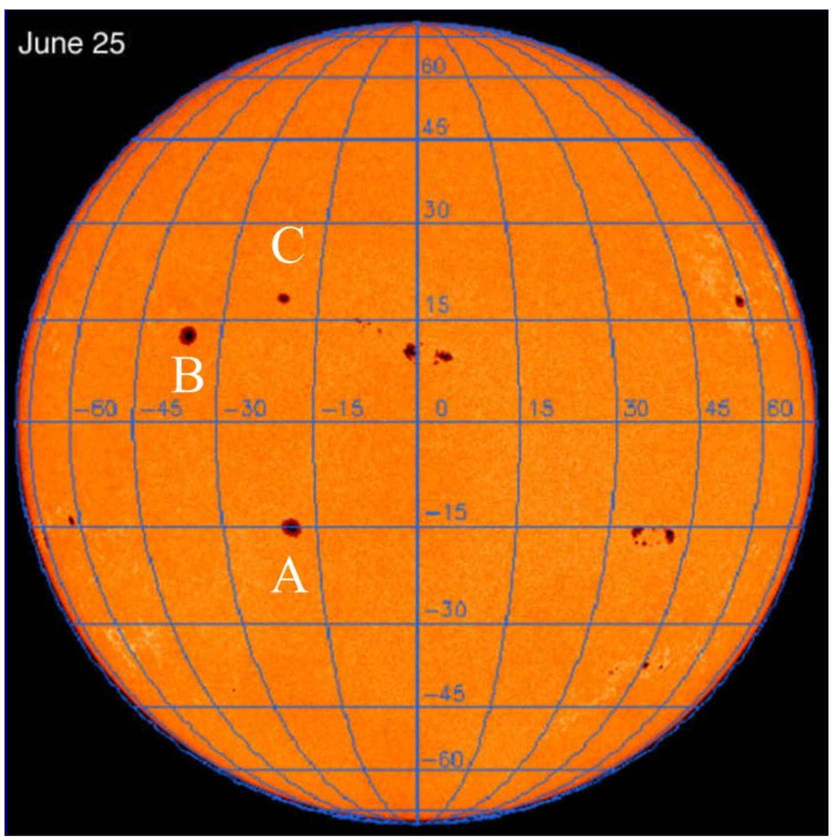
20. Thinking about all the surface features of the Sun, why would it be useful to follow and predict when sunspots will appear?


June 22
C
A
60
45
30
15
-60
-45
-30
-15
0
15
30
45
60
-15
-30
-45
-60

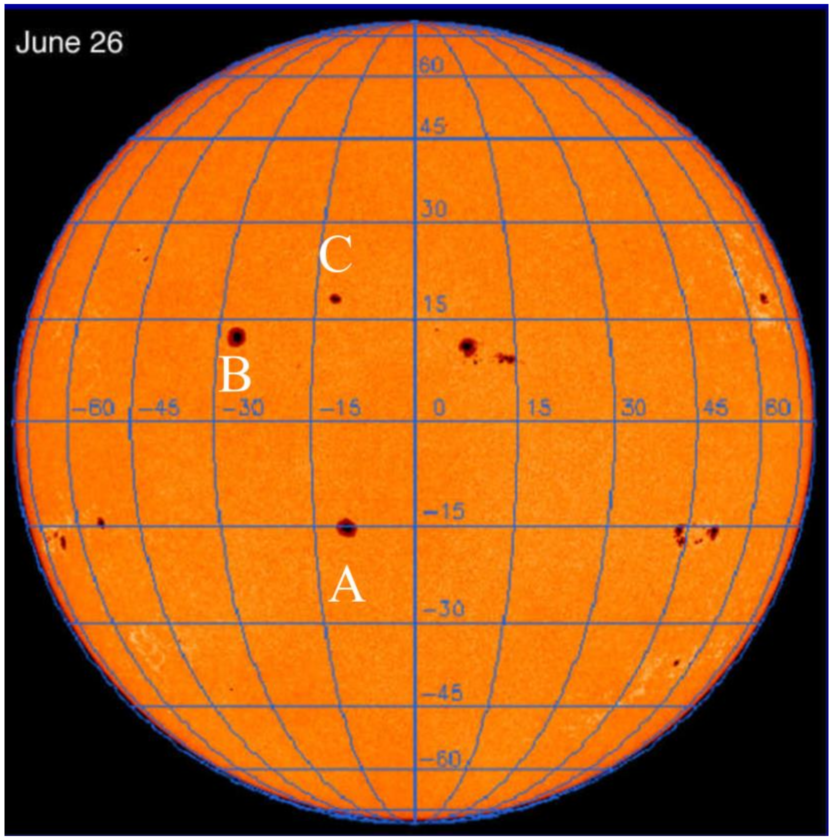

June 23
C
B
A
60
45
30
15
-60
-45
-30
-15
0
15
30
45
60
-15
-30
-45
-60

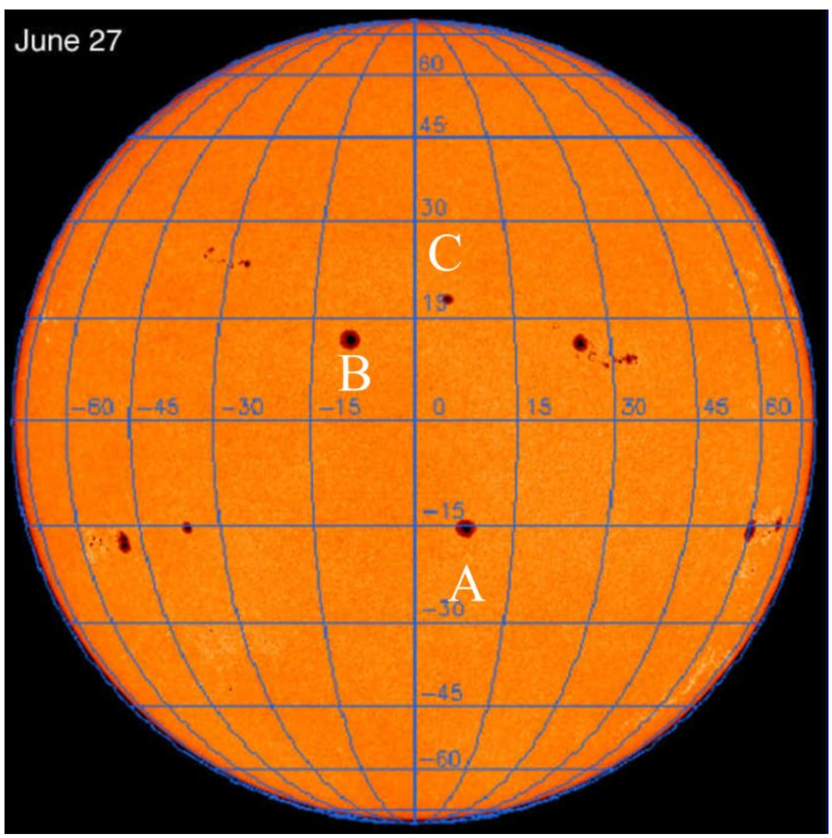


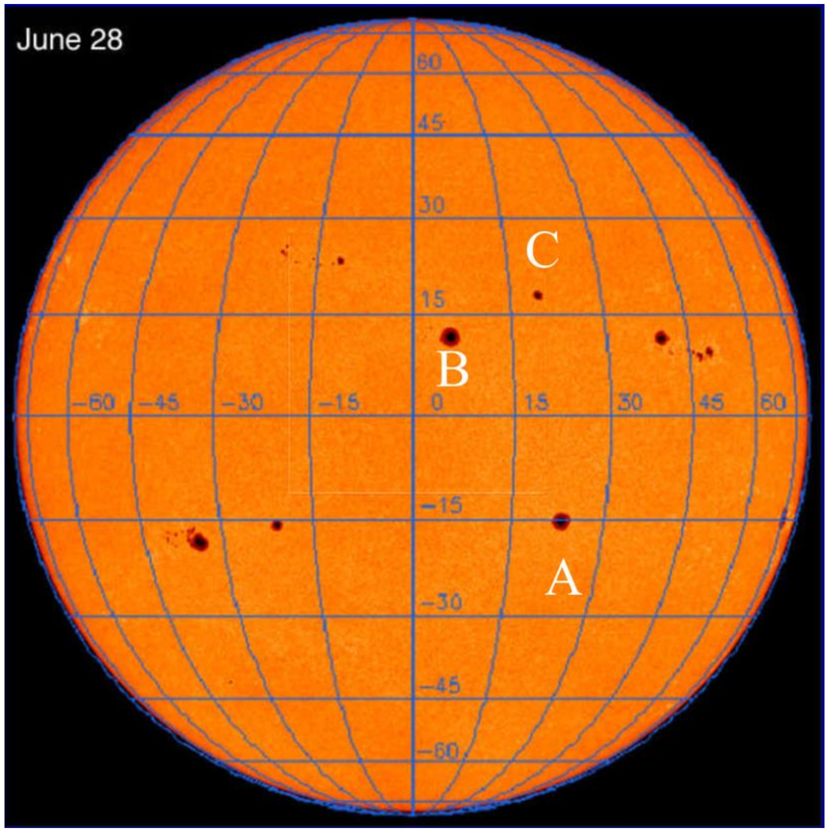
June 24
C
B
A
60
45
30
15
-60
-45
-30
-15
0
15
30
45
60
-15
-30
-45
-60

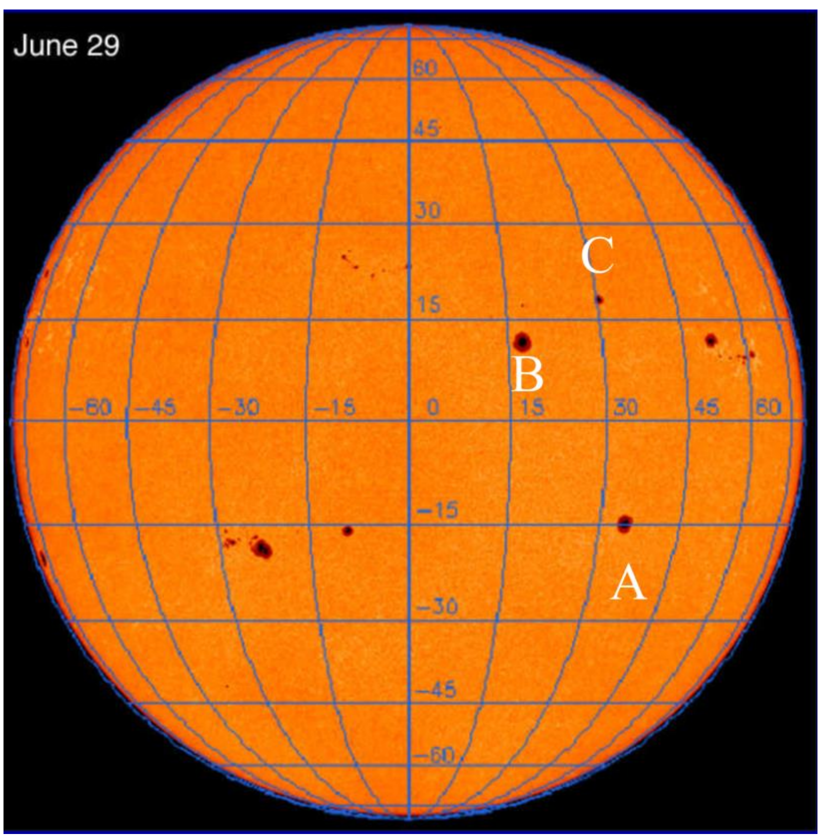


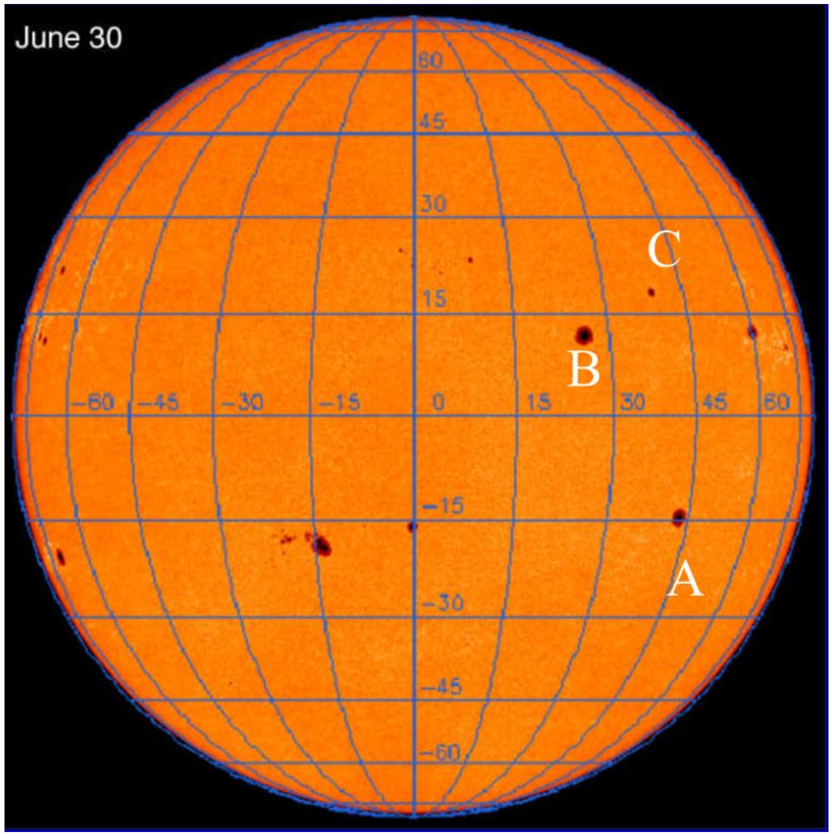
June 25
C
B
A
60
45
30
15
-60
-45
-30
-15
0
15
30
45
60
-15
-30
-45
-60

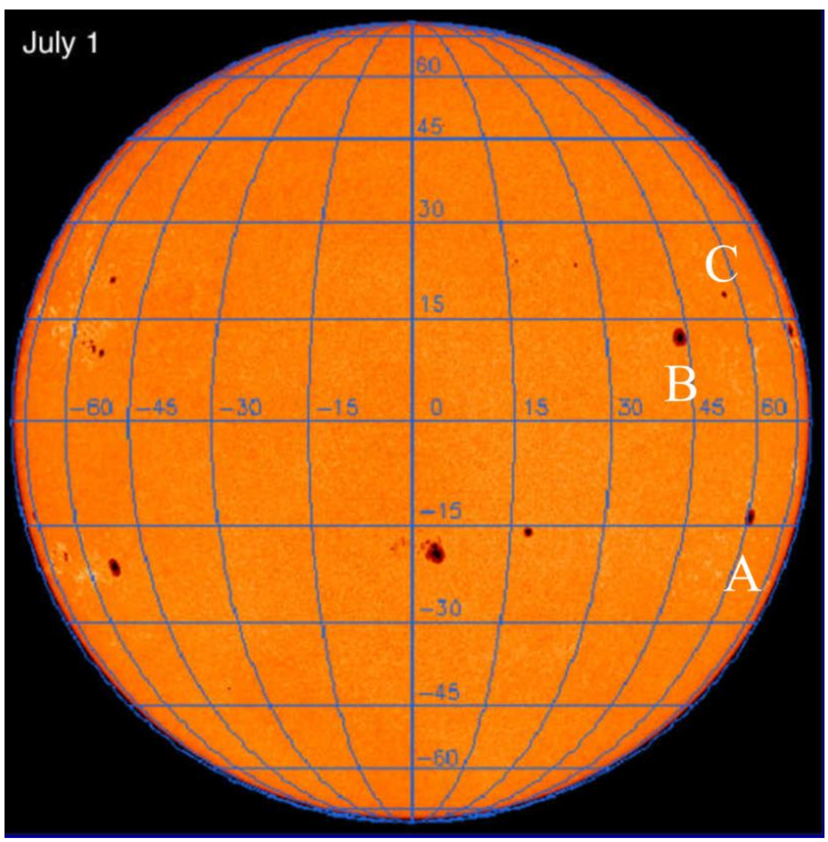

June 26
60
45
30
C
15
B
-60
-45
-30
-15
0
15
30
45
60
-15
A
-30
-45
-60

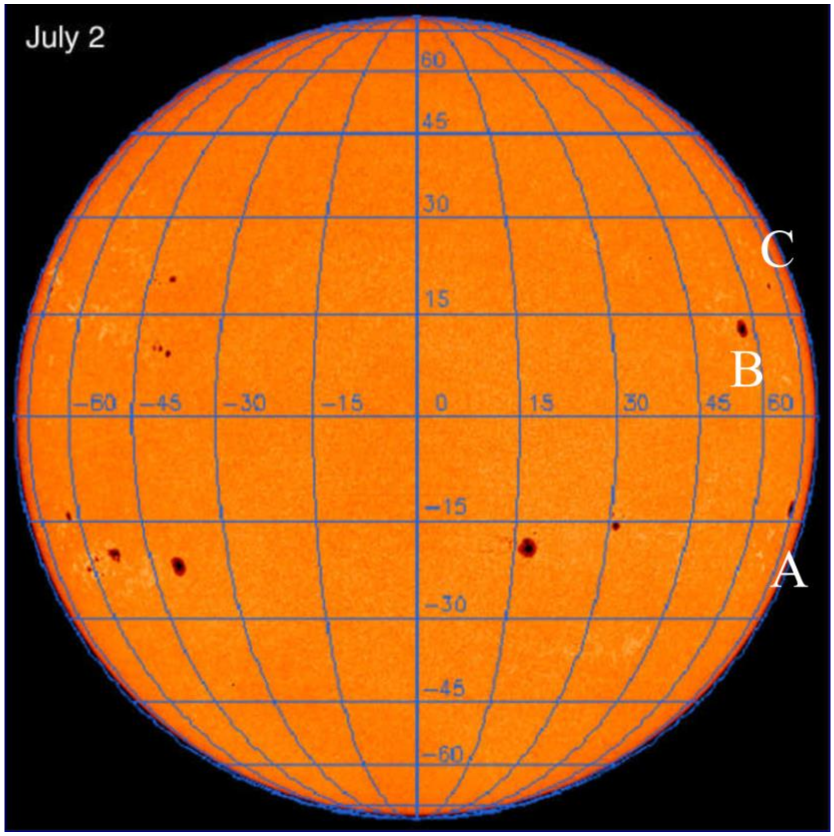

June 27
60
45
30
C
15
B
-60
-45
-30
-15
0
15
30
45
60
-15
A
-30
-45
-60


June 28
60
45
30
C
15
B
-60 -45 -30 -15 0 15 30 45 60
-15
A
-30
-45
-60

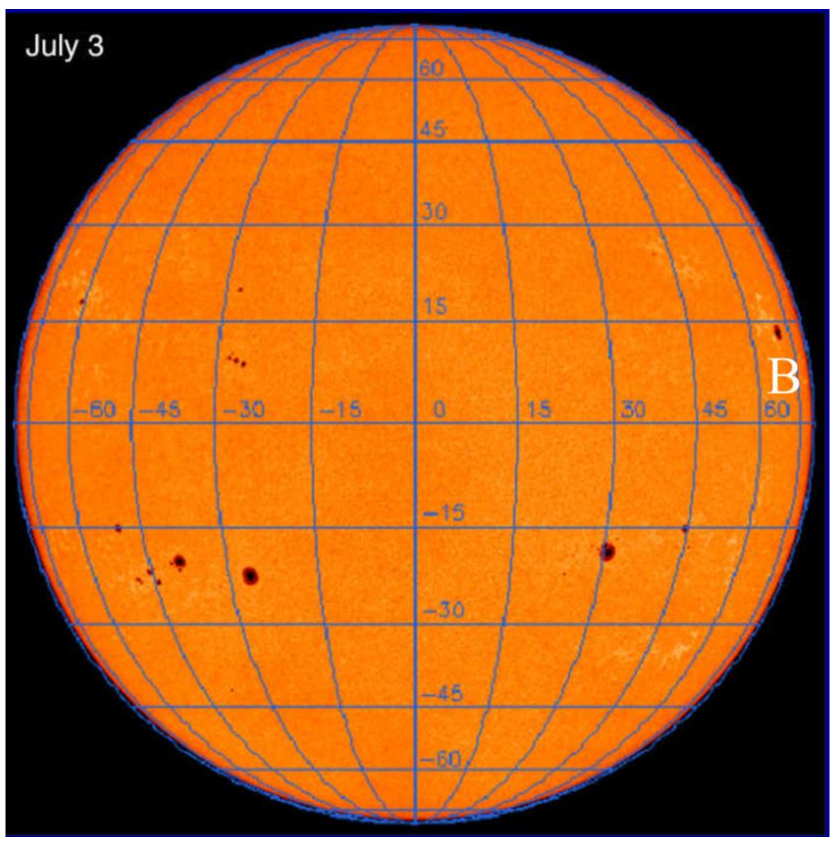

June 29
60
45
30
C
15
B
-60 -45 -30 -15 0 15 30 45 60
-15
A
-30
-45
-60


June 30
60
45
30
C
15
B
-60
-45
-30
-15
0
15
30
45
60
-15
A
-30
-45
-60


July 1
60
45
30
C
15
B
-60
-45
-30
-15
0
15
30
45
60
-15
A
-30
-45
-60



July 2
60
45
30
C
15
B
-60
-45
-30
-15
0
15
30
45
60
-15
A
-30
-45
-60



July 3
60
45
30
15
B
-60
-45
-30
-15
0
15
30
45
60
-15
-30
-45
-60